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# Rheological, bioactive and sensory properties of dark chocolates elaborated with stevia sweetener and freeze-dried berries

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ABSTRACT

The chocolate industry is progressively seeking to incorporate novel ingredients in order to satisfy the demand for innovative products. Nevertheless, the modification of formulations in chocolates can result in alterations to their properties. This study aimed to evaluate the rheological, bioactive and sensory properties of dark chocolates by adding freeze-dried berries and stevia sweetener. The chocolate tablets were formulated with four dried berry pulps and three doses of stevia sweetener. It was found that the addition of stevia at any of the concentrations tested increased the viscosity (2.97 ± 3.84 Pa-s), yield strength (11.6–17.6 Pa), and hardness (42.06 ± 3.10 N) of the chocolates, benefiting the texture and heat resistance of dark chocolates. Moreover, the incorporation of stevia resulted in enhanced thermal stability and antioxidant capacity, indicating a probable enhancement in product quality. The chocolates containing blackberry and a stevia sweetener concentration of 0.2 % received the highest ratings for color (7.46 ± 0.20), while those containing blueberry and a stevia sweetener concentration of 0.4 % received the highest ratings for texture and flavour (7.66 ± 0.90). In conclusion, this work demonstrated that the incorporation of stevia sweetener and dehydrated berry pulp can improve the physicochemical and sensory characteristics of dark chocolates, improving their thermal stability and sensory acceptability.

## 1. Introduction

Chocolate is a highly valued food for its sensory and bioactive characteristics (Afoakwa et al., 2008; Lončarević et al., 2018), and its high energy content, texture, and flavor makes it a product with high consumer acceptance (Balcázar-Zumaeta et al., 2023; Tan & Balasubramanian, 2017). Nowadays, more conscious consumers are open to functional chocolates, so the growing demand for functional foods has prompted the chocolate industry to develop new formulations that incorporate functional ingredients and alternatives to refined sugar, such as stevia. These formulations are promising strategies to reduce sugar content and improve the nutritional profile of chocolates (Balcázar-Zumaeta et al., 2023; Castro-Alayo et al., 2019).

Berries, such as blueberrie (*Vaccinum corymbosum*), goldenberry (*Physalis peruviana*), and blackberrie (*Rubus ulmifolius*), are rich in antioxidants, vitamins, minerals, and dietary fiber, which could improve the nutritional profile and bioactive properties of chocolate (James et al., 2022). However, the addition of these ingredients carries on technical challenges for manufacturers. The addition of berries can alter the viscosity, texture, and tempering process during processing of chocolate. It is imperative to assess the impact of these rheological alterations on the flavour, aroma and texture of the product, given the fact that these characteristics exert a direct influence on consumer acceptance (Mahato et al., 2022; Statista, 2022).

Previous research has shown that sugar substitutes (non-caloric sweeteners) and fruit derivatives of high nutritional value can be

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incorporated into traditional chocolate formulations (Asghari et al., 2023; Rezende et al., 2015). As a case in point, the incorporation of sweeteners other than sucrose, such as fructose and sugar alcohols, has been demonstrated to enhance the hardness of chocolates. Conversely, the addition of stevia and mint leaves to chocolates has been shown to improve their taste (Belščak-Cvitanović et al., 2015). Furthermore, the microstructure of the chocolate is denser, which prevents the undesirable phenomenon of fat bloom, which occurs during storage (Rodriguez et al., 2017).

The combined effect of dehydrated berry pulp and stevia sweetener on the properties of dark chocolates has not yet been tested, and these results need to be compared with a standard cocoa and sugar formulation. Therefore, the objective was to evaluate the physicochemical and sensory properties of dark chocolates elaborated with freeze-dried berries and stevia sweetener.

## 2. Methodology

### 2.1. Materials

The chocolates were manufactured using criollo cocoa paste, which was cultivated in the Amazon region of Peru. The paste was obtained by the research team from dried fermented cocoa beans. The cocoa butter, sugar and sweeteners were procured from the Central Market in the city of Chachapoyas, Amazonas, Peru.

### 2.2. Acquisition and pretreatment of fruit (berries)

Fresh blackberries (*Rubus ulmifolius*), blueberries (*Vaccinium corymbosum*), and goldenberry (*Physalis peruviana*) were transported to the Cacao Quality Control Laboratory. They were manually selected to eliminate foreign materials such as leaves, soil, and stems. Subsequently, the fruits were washed with potable water and disinfected with a 0.01 % sodium hypochlorite solution for 5 min Muñoz-Castellanos et al. (2021).

### 2.3. Obtaining freeze-dried berry pulp

Fruits were crushed in a domestic blender (Oster) and juices were volumized in 50 mL falcon tubes, and put right after in an ultra-freezer (New Brunswick, UK) at −86 °C for 72 h; then freeze-dried (LABCONCO, Canada) for 72 h at 0.360 mbar and 75.8 °C (Huaman-Rojas et al., 2024). Freeze-dried fruit pulps were ground in a grain mill (Bosch, China) and stored under refrigeration in airtight bags until further use.

### 2.4. Preparation of chocolate with the incorporation of freeze-dried berry pulp

Dried fermented cocoa beans at 7 % moisture content were roasted in an oven (MMM Group, Venticell ECO Line, Germany) at 115 °C for 45 min Afoakwa et al. (2007), ground in a bean mill (Prosol SAC, Tritur-50) to separate the shell from the nibs, and refined for 5 h in granite refiners (Premier, India) of 3.5 kg capacity. Different formulations were followed to elaborate 70 % dark chocolates (Table 1). On the other hand, the control treatment consisted of 65 % cocoa liquor, 5 % cocoa butter and 30 % sugar. The refining process of formulations was carried out for 16 h. The stevia sweetener was added at the beginning of the refining process and at the end of this process, the chocolate was tempered manually using a temperature variation cycle: first, the temperature increased to 45 °C in a water bath. Then, pre-crystallization of the mass was carried out on a stainless-steel table at 27 °C to sort out the cocoa butter crystals. The mass was then molded at 32 °C in polycarbonate molds for 14 × 12 × 0.6 cm 50 g tablets and 1 × 1 × 0.5 cm tablets (Leite et al., 2013). All formulations were carried out in triplicate. The chocolates were wrapped in aluminum foil and stored at 18 °C until further analysis.

In order to ascertain the appropriate levels of stevia sweetener to be employed, preliminary tests were conducted with the research team to determine detection and tolerance levels in chocolates.

**Table 1**
Formulation of dark chocolates with the addition of stevia-sweetened berry pulp.

| Berry type | Dehydrated fruit pulp content (%) | Stevia sweetener (%) | Powdered milk/ sugar (%) | Cocoa (%) |
|---|---|---|---|---|
| Control (without fruit or sweetener) | 0.0 | 0.0 | 30* | 70 |
| Blueberry | 2 | 0.2 | 28.8 | 70 |
| | 2 | 0.3 | 28.7 | 70 |
| | 2 | 0.4 | 28.6 | 70 |
| Goldenberry | 2 | 0.2 | 28.8 | 70 |
| | 2 | 0.3 | 28.7 | 70 |
| | 2 | 0.4 | 28.6 | 70 |
| Blackberry | 2 | 0.2 | 28.8 | 70 |
| | 2 | 0.3 | 28.7 | 70 |
| | 2 | 0.4 | 28.6 | 70 |

Note: All values are expressed in % (p/p). *Sugar.

### 2.5. Physicochemical properties of dark chocolate with freeze-dried berry pulp sweetened with stevia

a) **Viscosity**

The viscosity of the chocolate suspensions was determined following Abdul Halim et al. (2019), using a modular compact rheometer (Anton Paar, Model MCR 302e) equipped with a CC27 concentric cylinder geometry. The samples were melted at 40 °C in an oven (Venticell Ecoline, Germany) for 60 min. Then, 25 mL of the melted solution was added to the cup from the rheometer, and the temperature of the Peltier coupled to the equipment was adjusted to 40 °C. The measurements started with a preconditioning step at 40 °C for 60 s. Then, measurements were taken with the RheoCompass software using the Casson Model (Eq. (1)):

$$\sigma^{0.5} = (\sigma_0)^{0.5} + K_1(\gamma)^{0.5} \quad (1)$$

Where σ (Pa) is the shear stress, σ0 is the Casson yield stress (Pa), $K_1$ is the consistency index (Pa. s), and γ (s-1) is the shear rate.

The rotational rheological measurements were expressed as Casson plastic viscosity (Pa. s) and Casson yield stress (Pa). Each measurement was performed in triplicate.

b) **Hardness**

The hardness of chocolate bars was measured using a CTX texture analyzer (AMETEK, Brookfield with Textura Pro 1.0.19 software, USA) equipped with a 30° conical probe and a 10 kg load cell. The test was performed at a speed of 10 mm/s with an initial speed of 5 mm/s and penetration distance of 0.8 mm. The hardness of the specimens was recorded as the maximum force at the defined penetration distance. The measurements were performed in triplicate following Lillah et al. (2017).

c) **Particle size**

The particle size was determined following Ibrahim et al. (2020), with some modifications. 50 % melted chocolate and 50 % sunflower oil were placed in a beaker. Then, a drop of the solution was added into the jaws of the micrometer (MITUTOYO, Japan)and closed for reading, and the measurements were recorded in triplicate.

d) **Microstructure**

1 g of sample was melted in oven (Venticell Ecoline, Germany) at 55

°C for 20 min. Then, 10 μL of the melted material was placed on a glass slide and covered with a coverslip parallel to the slide's plane, ensuring the dispersion was homogeneous. Images of the chocolate microstructure were obtained at 20X magnification and captured with a DP74 camera, following previous methods (Afoakwa et al., 2007; Lapčíková et al., 2022).

e) **Whiteness index**

The whiteness index (WI) was calculated following Jin et al. (2024). The change in whiteness index (WI) was calculated by comparing the WI values on each test day with the WI value on day 0 ($WI_0$). A standard plate (L* = 88.19, a* = 0.82, b* = 1.17) was used to calibrate the surface color (L*, a* and b* values) of the chocolate on days 10, 20, 30, 40, 50, 60 of storage, with a CR-400 automatic colorimeter (Konica Minolta, Australia). This allowed to track the degree of fat bloom during storage.

f) **Melting properties**

The thermal behavior of chocolates was evaluated according to Calva-Estrada et al. (2020), by differential scanning calorimetry (DSC) with DSC-60 plus equipment (DSC-60 plus, Japan). The equipment was left on for 30 min to stabilize the electronic system and the oven. Subsequently, 2.5 ± 0.5 mg of chocolate was weighed on an analytical balance (VWR-503R2), placed in hermetically sealed aluminum vials, and placed to the DSC oven. An empty sealed aluminum cuvette served as a blank, and a 25 mL/min nitrogen flow rate at normal pressure was used. The samples were melted at a temperature of 60 °C for 20 min. For each peak present in the thermogram obtained, the onset temperature (°T onset), end temperature (°T end), and enthalpy (°T end) were calculated (ΔH) (Gloria & Sievert, 2001).

g) **Determination of antioxidant capacity**

**Defatting of samples**

The chocolate samples were defatted according to Suazo et al. (2014). Then, 10 mL of hexane (HPLC,99.7 %, Merck) was added to 2 g of ground and sieved sample. Mixtures were stirred at 300 rpm for 20 min in orbital Shaker (Lauda, Germany BS150), and centrifuged at 3000 rpm at room temperature for 15 min using PrO-Analytical centrifuge. The supernatant was placed in a fume hood (Labconco, USA) for 48 h to remove the hexane present and recover the defatted sample.

**Antioxidant capacity**

For the preparation of the methanolic solution (80 % (w/v)) of the DPPH radical, we followed Jonfia-Essien et al. (2008). 100 mg of defatted chocolate sample was mixed with 10 mL of 80 % methanol solution, stirred at 3000 rpm for 15 min, centrifuged at 4830 rpm for 30 min, and filtered on paper (Whatman N° 40- 2.5 μm). The supernatant was stored at −20 °C until further analysis.

The antioxidant activity of chocolate extracts elaborated with dried berries was determined by the DPPH free radical scavenging assay. The methanolic solution was prepared at 0.1 mM DPPH. Then, 2 mL of this solution was placed in a test tube, and 200 μL of the extract was added. The mixture was shaken and incubated at room temperature (average 18 °C) under dark conditions. The absorbance of the solution was measured with a spectrophotometer (T 9200 PEAK Instruments, USA) at a wavelength of 517 nm. The percentage inhibition was calculated with Eq. (2).

$$\%\ inhibition\ of\ DPPH = \frac{(A0 - AS) - (AT - AS)}{(A0 - AS)} X\ 100 \quad (2)$$

Where: $A_0$: Absorbance of DPPH solution, $A_s$: Absorbance of methanol, $A_T$: Absorbance of sample.

h) **Total phenols content**

The total phenolic content was determined according to Singleton et al. (1999), with some modifications. To prepare the extract, 1 g of defatted sample was mixed with 10 mL of methanol-water (80:20, v/v) as described in Brand-Williams et al. (1995). Then, 0.1 mL of extract was mixed with 2.5 mL of Folin-Ciocalteu reagent, and 2 mL of sodium carbonate solution was added. The reagents were shaken for 20 s with a vortex (VWR Analog Vortex Mixer, US). The solution was then allowed to stand in the dark for 2 h before measuring the absorbance at 760 nm (Emelab Spectrophotometer, Germany). The calibration curve was performed with gallic acid at different concentrations (10–100 μg/mL). Total phenolic content was expressed as mg of gallic acid equivalents per gram of sample (mg GAE/100 g).

i) **Total anthocyanins content**

The total anthocyanin content was determined according to the AOAC (1995) with some modifications. The absorbance of the methanolic extract was measured at a wavelength of 535 nm in a UV–vis spectrophotometer (T 9200 PEAK Instruments, USA). The results of total anthocyanins in the samples were expressed as mg of total anthocyanins per 100 g of sample (Eq. (3)).

$$C(mg / 100g) = A\lambda_{max} / E^{1\%}_{1cm} \quad (3)$$

Where: C: Concentration in mg/100 g; A: Absorbance λ_max of 535 nm; Specific absorbance $E^{1\%}_{1cm}$=98.2

j) **Sensory acceptance**

The sensory evaluation followed Ibrahim et al. (2020). A 9-point Likert-type test was used with 60 semi-trained panelists. Each panelist tasted the chocolate and answered the sensory test according to chocolate attributes (color, smoothness, flavor, and overall acceptability).

### 2.6. *Data analysis*

Treatments were compared using an analysis of variance (ANOVA) followed by Tukey's multiple comparisons test at 95 % confidence level. The R packages "stats" and "agricolae" (Rstudio, version 4.3.3, Boston, MA, USA) were used.

## 3. Results and discussion

### 3.1. *Viscosity*

The of viscosity chocolates elaborated with freeze-dried goldenberries and blueberries increased (2.97 ± 0.01 Pa.s) as stevia dose increased (0.2 to 0.4 %), while the viscosity of the control chocolate presented values of 2.76 ± 0.01 Pa.s. Viscosity is crucial in the manufacture of chocolate to obtain final products with well-defined textures. The reference values for Casson viscosity in dark chocolates is between 2.1 and 3.9 Pa.s (Aidoo et al., 2015; Azevedo et al., 2016). Chocolates with higher viscosity values have a pasty sensation and melt slowly in the mouth (Afoakwa et al., 2007). The increase in viscosity tends to be due to the composition of the berries added (Pajin et al., 2013). However, dark chocolates incorporating freeze-dried blackberry pulp showed an opposite behavior (Fig. 1). At higher doses of stevia sweetener, viscosity decreased, reaching 2.45 ± 0.01 Pa-s, a lower value than that of the control. This could be due to the substitution of stevia for sugar, which leads to a significant increase in precipitation and a decrease in viscosity (Pajin et al., 2013).

The rheological properties of dark chocolates are important in the manufacturing process to obtain high-quality products with well-defined textures (Servais et al., 2003). However, this property can be affected by the quality of the incorporated ingredients, such as fat, non-fat cocoa solids, and sugar content (Fernandes et al., 2013).

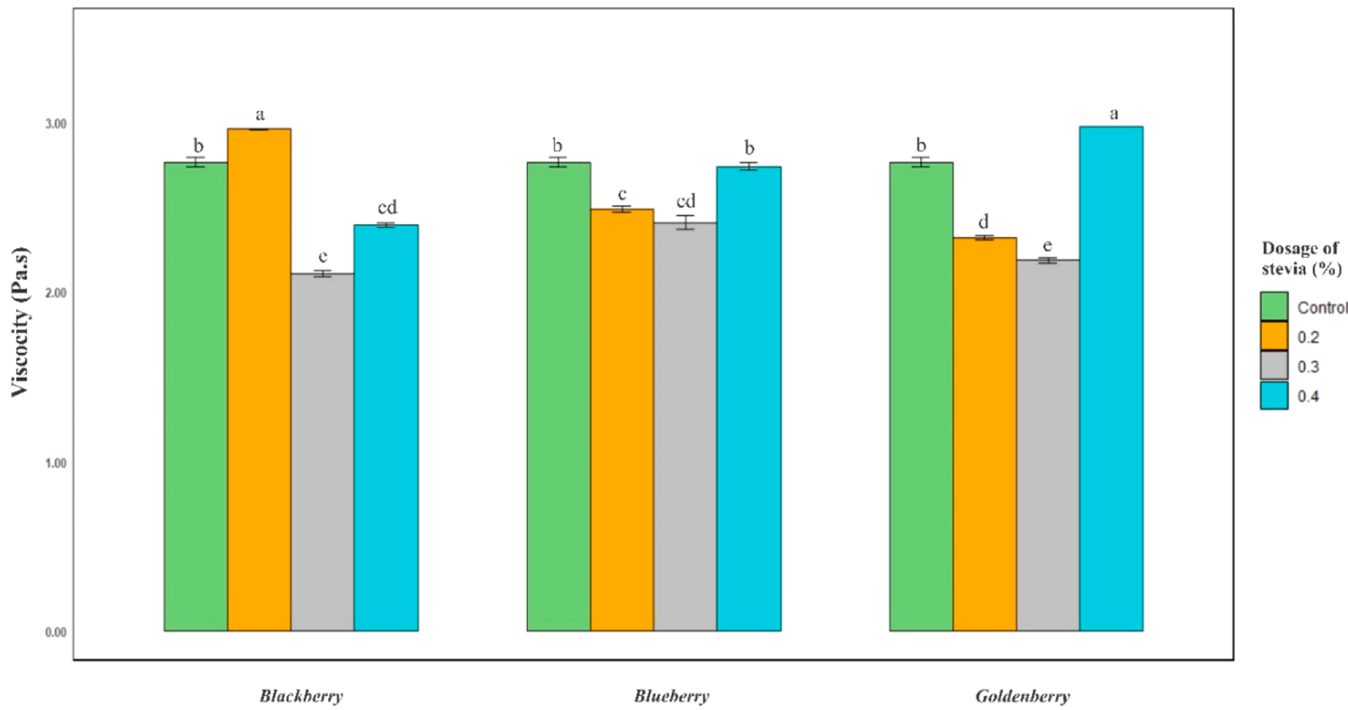


**Fig. 1.** Viscosity of dark chocolates incorporating berries and sweetened with stevia.

Fig. 2 shows the elastic limit values of the dark chocolates made with three types of dehydrated berries and three doses of stevia addition. The dark chocolates elaborated with goldenberry presented a decreasing tendency with higher doses of stevia and lower elastic limit. However, these values were lower than the control 26.08±0.05 Pa. This could be due to the synergistic effect between the fruits and the sweetener (Carrión-Espinosa et al., 2023).

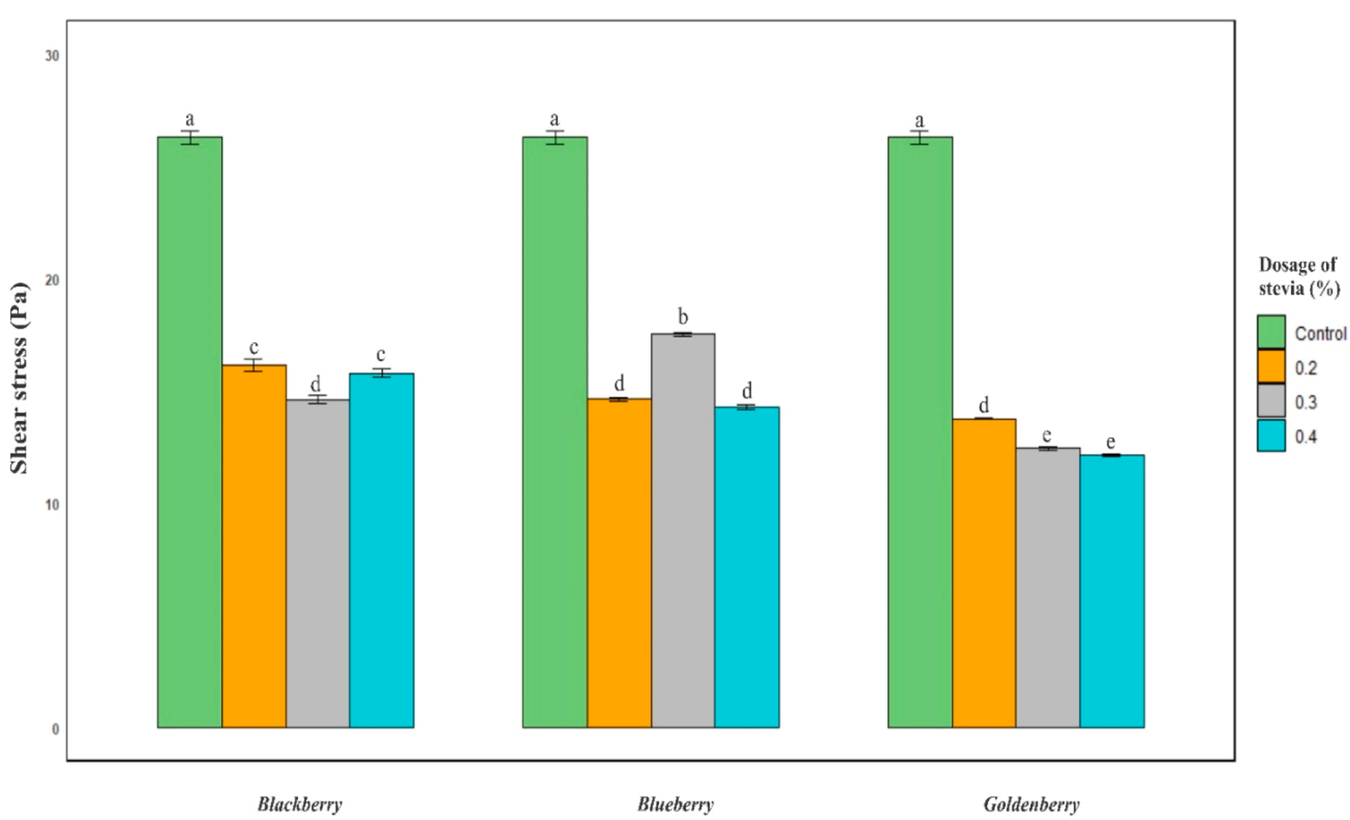


**Fig. 2.** Evaluation of shear stress of dark chocolates with berry incorporation.

### 3.2. Hardness

One of the most important properties of chocolate is texture, especially hardness, which affects quality and consumer perception (Camelo-Silva et al., 2024). Fig. 3 shows the hardness values of the dark chocolates. The control presented higher hardness (42.14±6.65 N) than the chocolates made with dehydrated berries and stevia sweetener. However, the chocolates with goldenberry presented higher hardness as the dose of stevia increased, reaching values up to 42.06 ± 3.10 N. The physical properties of chocolate depend on the behavior of the fat phase and the amount of fat present in the chocolate (Torbica et al., 2014). The inclusion of stevia sweetener significantly affected ($p < 0.05$) the characteristics of the chocolate. The higher the proportion of stevia, the greater the hardness of the tablets (Dewi et al., 2021). Previous studies have shown that the higher the dose of stevia, fructose, and isomaltose incorporated, the higher the hardness of the chocolates evaluated (Belščak-Cvitanović et al., 2015).

### 3.3. Particle size

Particle size distribution significantly impacts the structure of chocolate. Particle size influences key parameters such as yield strength, plastic viscosity, and hardness (Huaman-Rojas et al., 2024). The particle size depends on the type of berries and amount of sweetener used in the formulation (Fig. 4). It was found a significant difference between treatments ($p < 0.05$), whose values were between 60.0 ± 2.0 µm to 74.33 ± 3.05 µm compared to the control while the control chocolate had a particle size of 53.66 µm (Fig. 4). Belščak-Cvitanović et al. (2015) found that the particle size of chocolates increases when stevia and lactitol sweeteners are included.

### 3.4. Microstructure

In Fig. 5, the micrographs of the dark chocolates show an increase in the dispersion of their crystalline structure. The higher the dose of stevia, the higher the dispersion of the chocolate particles. In addition, it is observed that the dark chocolates, with the addition of goldenberry, presented greater dispersion in their structure.

### 3.5. Whiteness index

Fat bloom causes loss of gloss and undesirable smoothness on the chocolate's surface, which can adversely affect its consumption (Biswas et al., 2017). Fig. 6 shows the behavior of the whiteness index evaluated in dark chocolates during 60 days of storage. Chocolates with 0.4 % stevia presented the highest whiteness index values (Fig. 6a). There is no strong variation in the color index of the chocolates. A high whiteness index in chocolates indicates a lighter and brighter color, resulting from the optimal crystallization of the cocoa butter. This not only improves visual appearance but also suggests higher quality and freshness (Jin et al., 2019). In the case of dark chocolates with the addition of goldenberries (Fig. 6b), the higher the dose of stevia sweetener added, the higher the whiteness index of the dark chocolates up to 40 days, while at 60 days a considerable decrease was observed, which may be due to the stability of the chocolates and an adequate crystallization of the cocoa butter (Jurado Teixeira et al., 2016). Dark chocolates with the addition of 0.3 % freeze-dried blackberry (Fig. 6c) showed greater stability up to day 30 and then showed a decreasing behavior as storage time increased.

### 3.6. Melting properties

The maximum peak is reached when the rate of melting is greatest. The end of melting is the completion of liquefaction; and the width of the

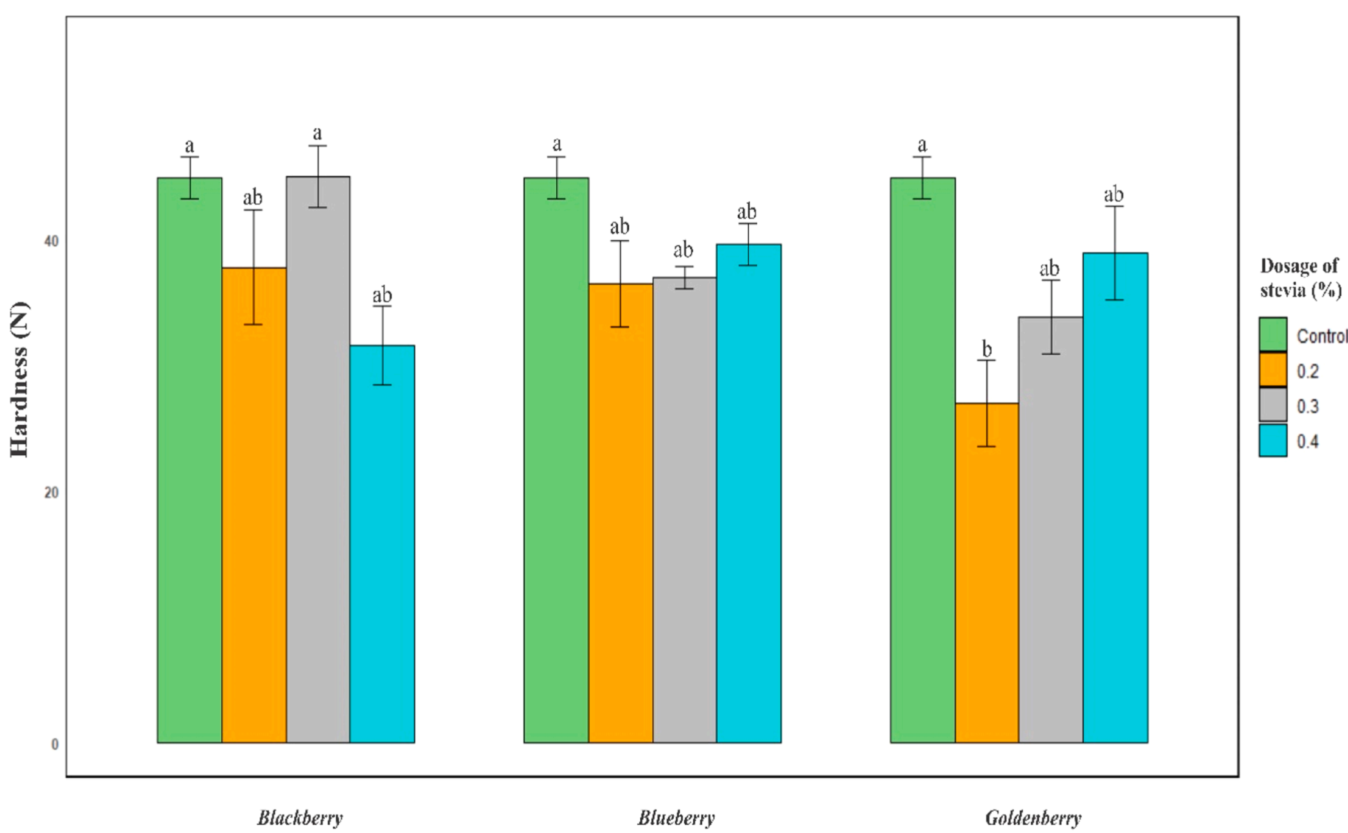


**Fig. 3.** Hardness of dark chocolates with berry incorporation.

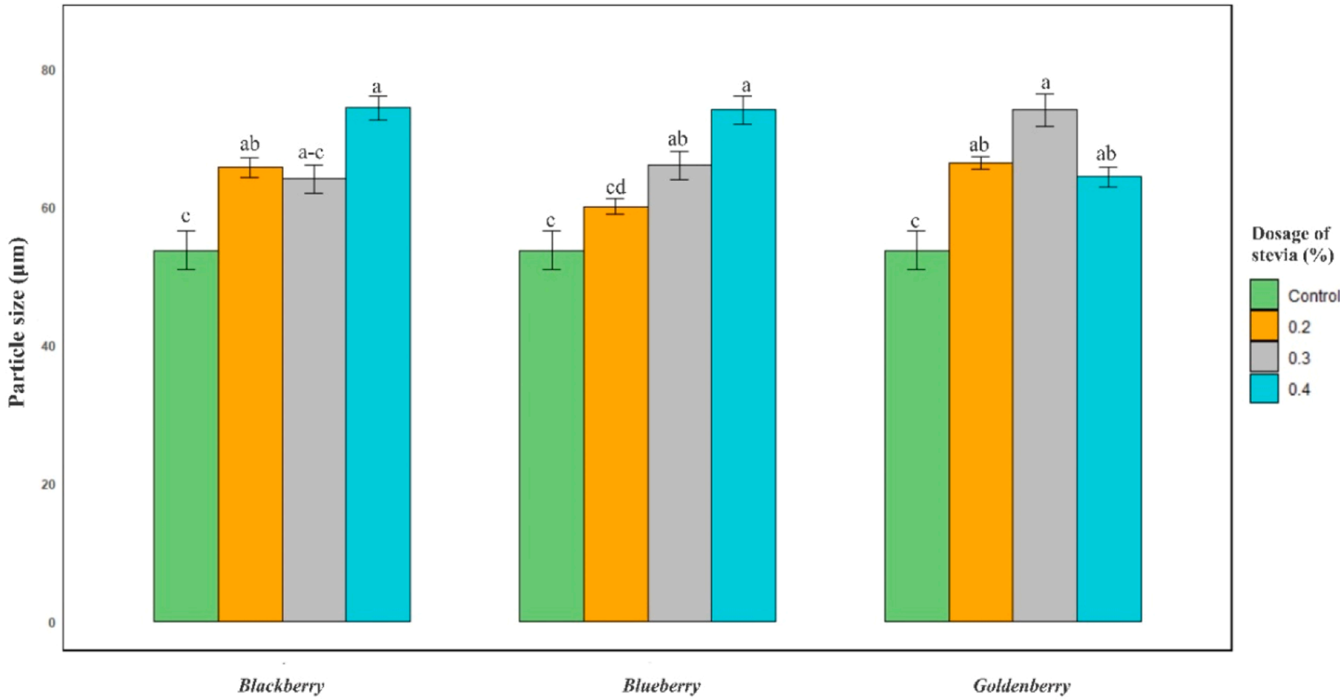


**Fig. 4.** Particle size of dark chocolates incorporating berries.

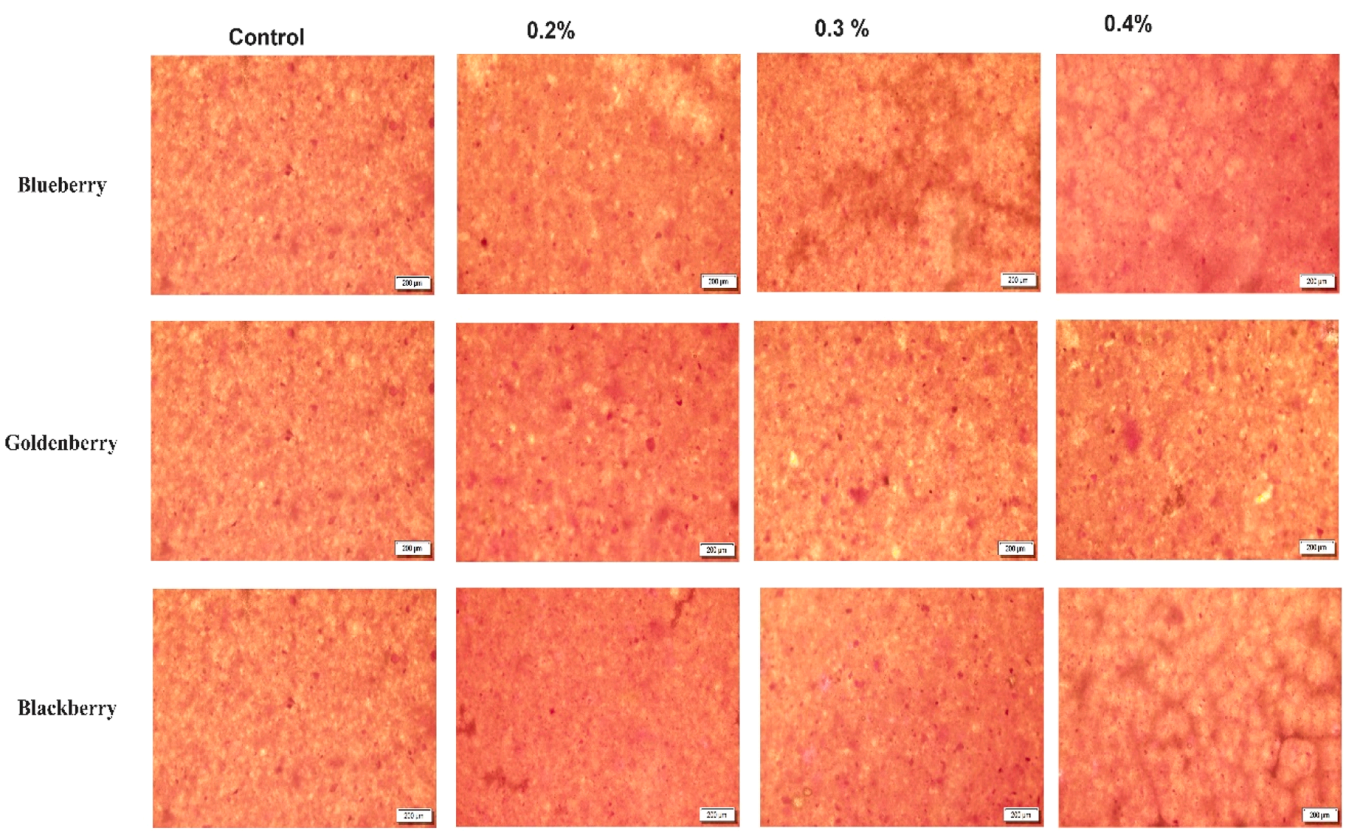


**Fig. 5.** Microstructure of dark chocolates incorporating berries and sweetened with stevia Scale bars = 2 mm.

peak at half the height indicates how long it took (duration) for a particular crystalline form to melt (Aidoo et al., 2015).

Table 2 shows the melting profiles obtained for each treatment. The dark chocolates had a maximum melting temperature between 31 and 32 °C with a ΔH of 76.58–110. 46 J/g. In the case of dark chocolates elaborated with dehydrated blueberries and blackberry, as the dose of sweetener addition increased, ΔH increased, suggesting that a greater amount of stevia could increase the thermal stability of the chocolate.

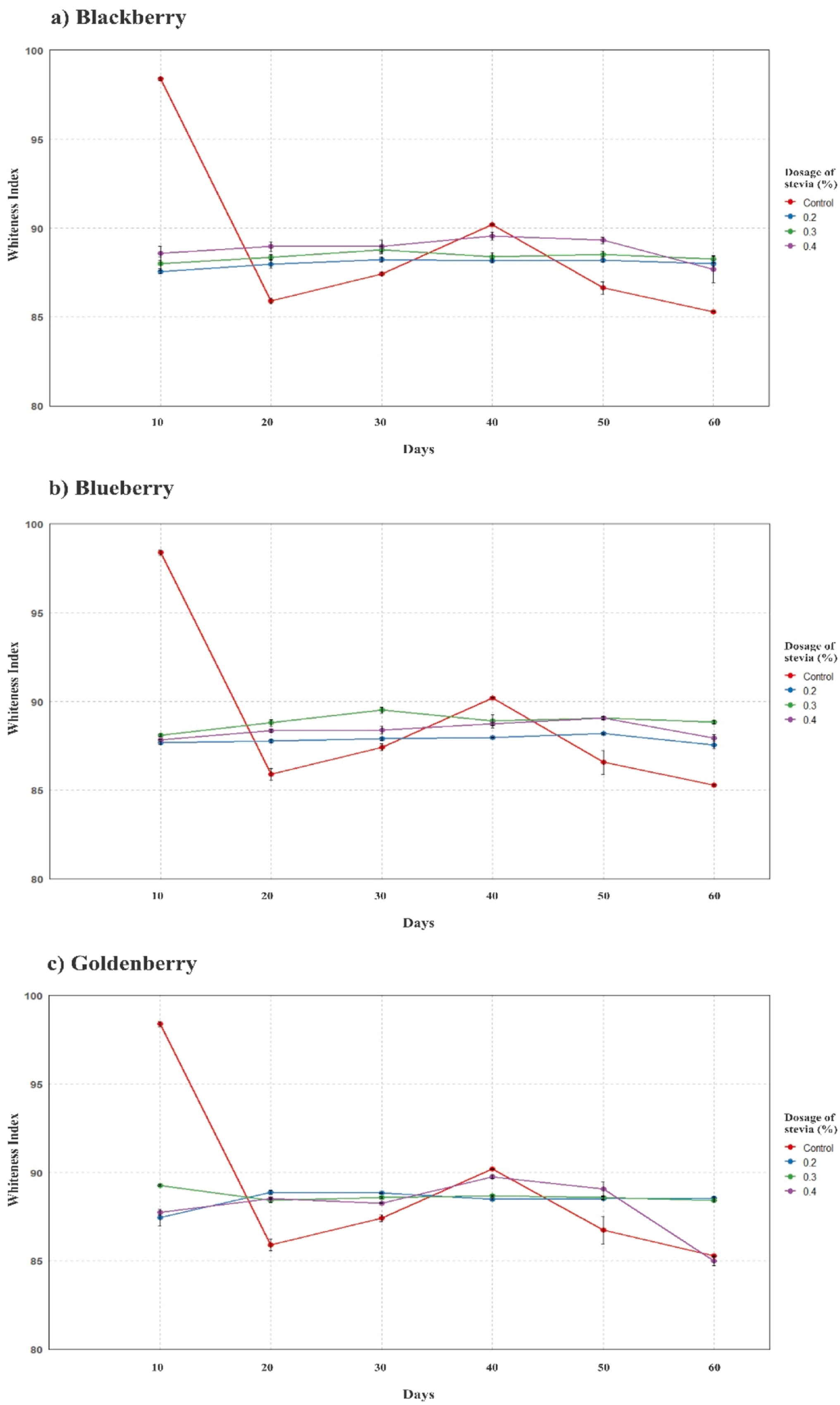


**Fig. 6.** Whiteness index of dark chocolates with berry incorporation and sweetened with stevia.

**Table 2**
Melting properties of dark chocolates incorporating stevia-sweetened berries.

| Type of chocolate | Stevia dosage (%) | $T_{onset}$(°C) | $T_{end}$ (°C) | $T_{peak}$(°C) | $\Delta H_m$ (J/g) |
|---|---|---|---|---|---|
| Control | 0.0 | 29.24 ±2.12 [ab] | 38.82 ±2.01[a] | 33.27 ±1.25[a] | 55.61 ±2.12[b] |
| Chocolate with blueberry | 0.2 | 30.77 ±0.96[ab] | 33.88 ±0.20[b] | 33.18 ±1.75[a] | 76.58 ±5.62[a] |
| | 0.3 | 28.83 ±1.88[ab] | 34.96 ±0.20[ab] | 32.06 ±0.38[a] | 96.13 ±2.21[a] |
| | 0.4 | 29.88 ±2.41[ab] | 35.36 ±0.70[ab] | 31.87 ±0.24[a] | 100.47 ±1.3[a] |
| Chocolate with goldenberry | 0.2 | 31.80 ±1.40[a] | 34.53 ±0.26[ab] | 32.13 ±0.26[a] | 96.47 ±1.37[a] |
| | 0.3 | 30.45 ±3.29[ab] | 34.69 ±0.69[ab] | 32.14 ±0.22[a] | 85.70 ±1.23[a] |
| | 0.4 | 26.11 ±0.29[b] | 35.56 ±0.81[ab] | 32.24 ±0.14[a] | 95.94 ±8.54[a] |
| Chocolate with blackberry | 0.2 | 28.74 ±2.45[ab] | 34.82 ±0.25[ab] | 31.82 ±0.35[a] | 89.09 ±1.02[a] |
| | 0.3 | 31.25 ±0.59[ab] | 34.58 ±0.23[ab] | 32.56 ±0.51[a] | 110.46 ±3.3[a] |
| | 0.4 | 31.84 ±1.24[a] | 34.93 ±0.26[a] | 32.96 ±0.30[a] | 110.43 ±1.1[a] |

Values are mean ± SD ($n$ = 3). Same columns with different subscripts are significantly different ($p < 0.05$).

However, in the case of chocolates with the incorporation of goldenberries, ΔH did not have the same tendency. All treatments showed significant differences ($p < 0.05$). The substitution of sucrose in some samples produced changes in crystallinity. The onset temperature was slightly higher compared to the control sample that reached 31.65±0.5 °C, which indicates a slight delay in the onset of melting, a beneficial property for industrialization since the chocolates would be more resistant to storage and distribution conditions in warmer climates (Aidoo et al., 2014).

### 3.7. Anthocyanins content

Fig. 7 shows the behavior of anthocyanins content in dark chocolates sweetened with stevia. In dark chocolates with dried goldenberry and blackberry, the anthocyanin content increased as the stevia addition dose increased. On the other hand, chocolates with blueberry addition showed a decrease in anthocyanin content as the stevia addition dose increased. This can be attributed to several factors, including chemical interactions that enhance the stability and solubility of anthocyanins, the relative concentration of ingredients, the effect of chocolate pH, improved dispersion of ingredients, and protection during processing (Azarpazhooh et al., 2021). It can be clearly seen that the incorporation of dehydrated berry pulp increases the anthocyanin content of the dark chocolates, as higher contents are observed than in the control treatment.

Table 3 shows the chocolates' total phenolic content and antioxidant capacity with dehydrated berries and stevia sweetener. It was observed that as the dose of stevia increased, the antioxidant capacity increased, reaching a maximum of 1.01 mmol/TE/L. In addition, a significant difference was found between treatments ($p < 0.05$). As for the phenolic content, dark chocolates with blackberry incorporation show an increase at a higher dose of stevia 6.08 (mg GAE/g). The addition of the sweetener allowed obtaining chocolates with a reduced content of reducing sugars, acceptable to consumers and with a significantly higher antioxidant activity compared with standard (Torri et al., 2017).

### 3.8. Sensory acceptance

Table 4 shows the scores assigned by the panelists to the chocolates made with dehydrated berries and sweetened with stevia. The chocolates made with blackberries and 0.2 % stevia reached the highest score

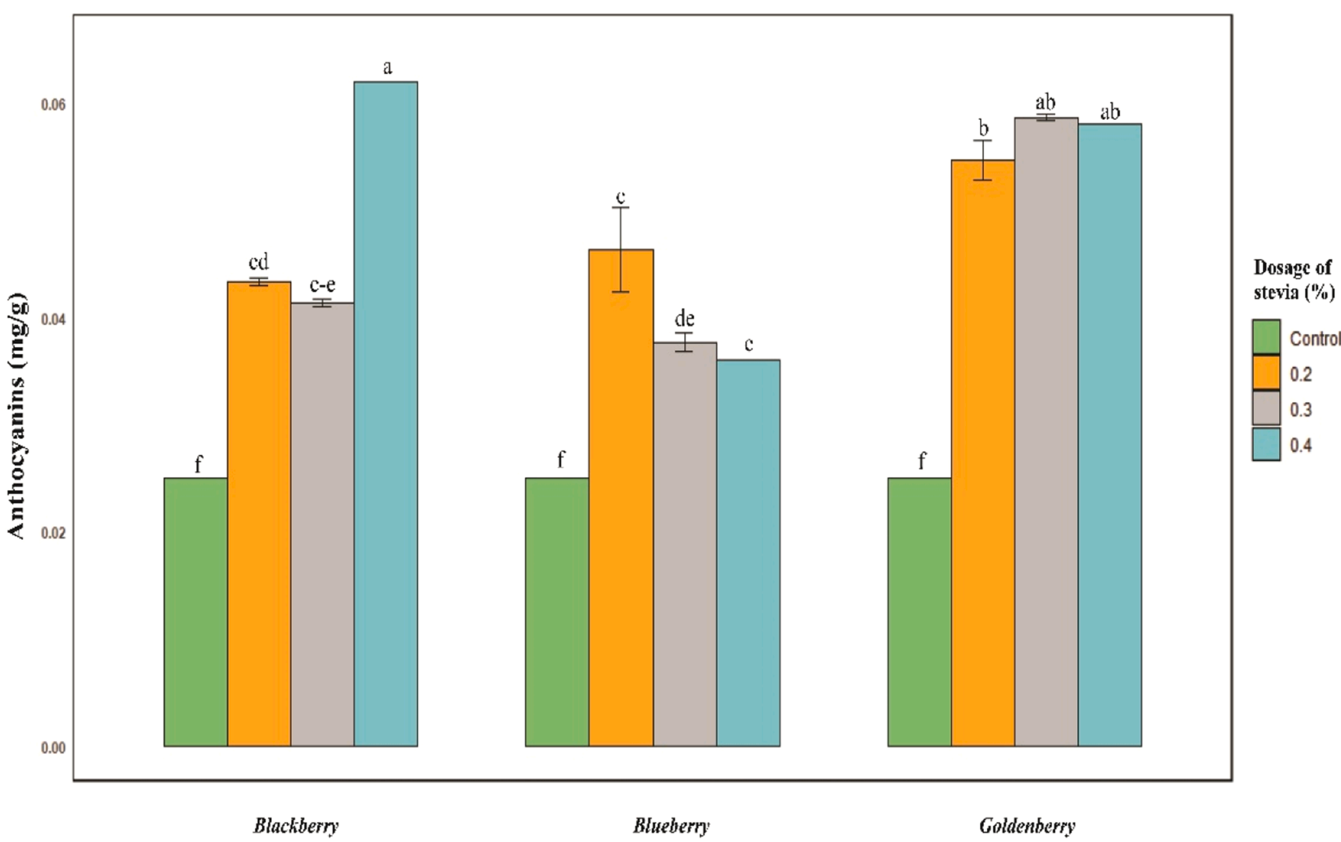


**Fig. 7.** Behavior of anthocyanins in dark chocolates with berries and sweetened with stevia.

**Table 3**
Antioxidant capacity of dark chocolates incorporating berries sweetened with stevia.

| Type of chocolate | Dosage of stevia ( %) | Antioxidant activity (mmol TE/L) | Total polyphenols (mg GAE/g) |
|---|---|---|---|
| Control | **0** | $0.28 \pm 0.05^{c}$ | $5.24 \pm 0.03^{b}$ |
| Chocolate with blueberry | 0.2 | $0.99 \pm 0.02^{ab}$ | $5.39 \pm 0.01^{ab}$ |
| | 0.3 | $0.99 \pm 0.04^{ab}$ | $5.26 \pm 0.03^{b}$ |
| | 0.4 | $1.01 \pm 0.04^{a}$ | $5.35 \pm 0.05^{b}$ |
| Chocolate with blackberry | 0.2 | $0.33 \pm 0.01^{b}$ | $5.24 \pm 0.01^{b}$ |
| | 0.3 | $0.34 \pm 0.11^{b}$ | $5.40 \pm 0.01^{ab}$ |
| | 0.4 | $0.34 \pm 0.04^{b}$ | $5.45 \pm 0.03^{ab}$ |
| Chocolate with goldenberry | 0.2 | $0.33 \pm 0.01^{b}$ | $6.08 \pm 0.03^{a}$ |
| | 0.3 | $0.33 \pm 0.01^{b}$ | $5.83 \pm 0.02^{ab}$ |
| | 0.4 | $0.34 \pm 0.05^{b}$ | $6.10 \pm 0.03^{a}$ |

Values are mean ± SD ($n = 3$). The same columns with different subscripts are significantly different ($p < 0.05$).

**Table 4**
Sensory analysis of dark chocolates elaborated with berries and stevia.

| Type of chocolate | Stevia dosage ( %) | Color | Texture | Flavor | Overall acceptability |
|---|---|---|---|---|---|
| Control | 0 | $6.85 \pm 0.02^{b}$ | $6.73 \pm 0.25^{b}$ | $5.50 \pm 022^{c}$ | $7 \pm 0.51$ |
| Chocolate with blueberry | 0.2 | $7.01 \pm 0.05^{b}$ | $7.10 \pm 0.50^{ab}$ | $6.66 \pm 0.50^{b}$ | $7 \pm 1.00$ |
| | 0.3 | $6.93 \pm 0.80^{b}$ | $6.31 \pm 0.70^{b}$ | $6.58 \pm 0.80^{b}$ | $7 \pm 0.95$ |
| | 0.4 | $7.16 \pm 0.65^{ab}$ | $7.66 \pm 0.90^{a}$ | $7.61 \pm 1.02^{a}$ | $7 \pm 0.95$ |
| Chocolate with blackberry | 0.2 | $7.46 \pm 0.20^{a}$ | $6.96 \pm 0.23^{b}$ | $6.88 \pm 1.02^{b}$ | $7 \pm 0.85$ |
| | 0.3 | $6.90 \pm 1.25^{b}$ | $6.98 \pm 0.21^{b}$ | $7.06 \pm 0.51^{ab}$ | $7 \pm 1.05$ |
| | 0.4 | $7.36 \pm 0.54^{ab}$ | $7.38 \pm 1.20^{ab}$ | $7.21 \pm 0.21^{ab}$ | $7 \pm 1.25$ |
| Chocolate with goldenberry | 0.2 | $7.41 \pm 0.20^{a}$ | $7.13 \pm 1.20^{b}$ | $6.83 \pm 1.02^{b}$ | $7 \pm 0.85$ |
| | 0.3 | $7.26 \pm 0.20^{ab}$ | $7.31 \pm 0.50^{ab}$ | $7.15 \pm 1.20^{ab}$ | $7 \pm 1.03$ |
| | 0.4 | $7.23 \pm 0.23^{ab}$ | $7.33 \pm 1.25^{ab}$ | $7.46 \pm 6.96^{a}$ | $7 \pm 0.96$ |

Values are mean ± SD ($n = 3$). Same columns with different subscripts are significantly different ($p < 0.05$), Tukey test.

of 7.46 for color, showing a difference between treatments ($p < 0.05$). Likewise, chocolates with blueberries and sweetened with 0.4 % stevia reached the highest score with 7.66. In flavor, the chocolates with the addition of goldenberries and 0.4 % stevia had higher flavor scores than the other formulations evaluated.

## 4. Conclusions

The physicochemical and sensory properties of the dark chocolates were influenced by the type of dehydrated berries incorporated (goldenberry, blueberries, and blackberries) and the addition of stevia sweetener.

Stevia sweetener inclusion increased the chocolates' viscosity, yield strength, and affect hardness, improving the sensory texture and heat resistance. In addition, it increased the chocolates' thermal stability and antioxidant capacity.

Finally, chocolates containing blackberries and 0.2 % stevia sweetener showed higher color, and visual appearance. On the other hand, chocolates with dehydrated blueberries and 0.4 % sweetener were the most valued for their texture and flavor, revealing a more complex sensory structure and greater acceptability.

Quality variables of chocolates that are affected by the incorporation of dehydrated berry pulp and natural stevia sweetener are demonstrated. Future studies could explore aspects associated with nutritional and chocolate stability during storage and acceptance by potential consumers.

## Ethics statement - studies in humans and animals

Based on Peruvian regulations, the approval of the ethics committee was not required for the sensory analysis in this research. Prior to the sensory analysis, participants were informed about the procedures, the composition of the chocolates, confidentiality and privacy, and the voluntary nature of their participation. All 60 panelists signed their participation in writing.

## CRediT authorship contribution statement

**Kiara Diaz:** Investigation, Formal analysis, Conceptualization. **Luz Quispe-Sanchez:** Supervision, Investigation, Formal analysis, Conceptualization. **César R. Balcázar-Zumaeta:** Supervision, Project administration, Conceptualization. **Robin Carli Oblitas:** Writing – original draft, Methodology, Investigation. **Roberto Mori:** Visualization, Supervision, Funding acquisition. **Sandra Mori:** Writing – original draft, Investigation, Data curation. **Toni Steven Chuquizuta:** Writing – review & editing, Methodology, Investigation. **Manuel Oliva:** Resources, Project administration, Funding acquisition, Conceptualization. **Segundo G. Chavez:** Writing – review & editing, Supervision, Project administration, Formal analysis, Conceptualization.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.afres.2025.100870.

## Data availability

Data will be made available on request.

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